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RESEARCH PAPER

Inventory Procedures for Smallholder and Community Woodlots in the Philippines: Methods, Initial Findings and Insights

J. L. Herbohn · J. Vanclay · H. Ngyuen · H. D. Le · J. Baynes · S. R. Harrison · E. Cedamon · C. Smith · J. Firn · N. O. Gregorio · E. Mangaoang · E. Lamarre

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Abstract This paper details the processes and challenges involved in collecting inventory data from smallholder and community woodlots on Leyte Island, Philippines. Over the period from 2005 through to 2012, 253 woodlots at 170 sites were sampled as part of a large multidisciplinary project, resulting in a substantial timber inventory database. The inventory was undertaken to provide information for three separate but interrelated studies, namely (1) tree growth, performance and timber availability from private smallholder woodlots on Leyte Island; (2) tree growth and performance of mixed-species plantings of native species; and (3) the assessment of reforestation outcomes from various forms of reforestation. A common procedure for establishing plots within each site was developed and applied in each study, although the basis of site selection varied. A two-stage probability proportion to size sampling framework was developed to select smallholder woodlots for inclusion in the inventory. In contrast, community-based forestry woodlots were selected using stratified random sampling. Challenges encountered in undertaking the inventory were mostly associated with the need to consult widely

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J. L. Herbohn · J. Vanclay
School of Environment, Science and Engineering, Southern Cross University, Lismore, NSW 2480, Australia

J. L. Herbohn (✉) · H. Ngyuen · H. D. Le · J. Baynes · S. R. Harrison · C. Smith · N. O. Gregorio
School of Agriculture and Food Sciences, The University of Queensland, St Lucia, Brisbane 4072, Australia
e-mail: john.herbohn@scu.edu.au

E. Cedamon · E. Mangaoang · E. Lamarre
College of Forestry and Natural Resources, Visayas State University, Visca, Baybay, Leyte 6521, Philippines

J. Firn
School of Biogeosciences, Queensland University of Technology, Brisbane 4001, Australia

before the commencement of the inventory and problems in identifying woodlots for inclusion. Most smallholder woodlots were only capable of producing merchantable volumes of less than 44 % of the site potential due to a lack of appropriate silviculture. There was a clear bimodal distribution of proportion that the woodlots comprised of the total smallholding area. This bimodality reflects two major motivations for smallholders to establish woodlots, namely timber production and to secure land tenure.

Keywords Trees outside forests · Rainforestation · Treefarm · Inventory method · Small-scale forestry · Community forestry · Reforestation

Introduction

Smallholder and community woodlots established by smallholders and communities are an important source of wood and other forest products, especially in many tropical countries (Harrison and Herbohn 2001; Lamb 2011). However, these woodlots are seldom included in formal national and regional inventories for several reasons, possibly the most important being the difficulty that can be associated with identifying woodlots. Common forest products for on-farm and community use include building materials, fuelwood, trellises for vegetables and fencing material. Woodlots can also be important sources of cash income. In the Philippines, small-scale woodlots (referred to locally as *treefarms*) are locally important as sources of wood for small-scale sawmills and to provide fuelwood and other non-timber products (Snelder and Lasco 2008).

Smallholder and community woodlots differ from industrial plantations in a number of important ways. Often, they are poorly managed relative to industrial estates (Harrison et al. 2002; Carle 2007). Thinning regimes are highly variable, with thinning often not undertaken, or done from above (i.e. biggest and best trees removed earliest leaving a degraded woodlot). Other silvicultural activities are often sub-optimal, e.g. weed control is poor and pruning is neglected. Poor silvicultural practices by smallholders and community members potentially lead to low quality trees and low site productivity. Small woodlots can be potentially important sources of biodiversity, especially in heavily disturbed landscapes. In aggregate, smallholder and community woodlots may be economically and environmentally important, and inventory data are valuable to understand the characteristics of these woodlots and how they may differ from traditional industrial-scale plantations.

At the stand or forest estate level, inventory information is important for planning and harvesting decisions, and for monitoring stand growth. Inventory data are also important input for timber industry planning and development purposes (e.g. Tomppo et al. 2011; Cedamon 2012). An important use of inventory data is for developing stand tables and growth models for the more commonly grown species, and especially the lesser known native species for which little information typically exists.

Smallholder and community woodlots sequester carbon and there is the potential for the sale of carbon into local and international markets. For example, reforestation and afforestation programs in developing countries can potentially qualify as Clean Development Mechanism (CDM) projects which generate Certified Emissions Reductions (CERs) that can be traded as greenhouse gas offsets (Dargusch et al.

2010), although to date currently few reforestation CDMs have been approved (Thomas et al. 2010). Inventory data are critical for estimating the carbon content of smallholder and community woodlots.

Despite the potential importance of smallholder and community woodlots in the tropics there are little published inventory data (e.g. area, species, standing volumes and ownership). Available information is largely restricted to surveys of the woodlot owners. These surveys, however, are often poorly designed and implemented, with limited or biased sampling frameworks and superficial analysis of the data collected.

Collecting inventory data related to smallholder and community woodlots presents a number of challenges. The woodlots are typically scattered through the landscape and are often very small in area, sometimes comprising only a few trees. Many are not recorded in official statistics or databases. The woodlot owners are seldom members of a forestry collective through which they can be contacted, and many do not live on the properties on which their woodlots are located. In the case of community-owned woodlots, the community organisations that are responsible for them can be difficult to contact, especially if the members are currently not actively involved.

The aims of this paper are to: (1) describe the processes and challenges involved in collecting inventory data from smallholder and community woodlots on Leyte Island, Philippines; (2) present initial findings from the inventory data collected to describe the smallholder and community timber resources; and (3) provide insights for the improved design and conducting of inventories of smallholder and community woodlots. The next section explains the motivation for collecting inventory data in the Leyte study site. The various steps applied in collecting and analysing inventory data are then described, including the sampling strategy for selecting and identifying municipalities from which to sample and the identification of woodlots within those municipalities. Characteristics of smallholder and community woodlots are then described and discussed.

Motivations for Collecting Inventory Data

Our motivation for collecting Leyte forest inventory data was the continuing smallholder and community forestry research program in the Philippines funded by the Australian Centre for International Agricultural Research (ACIAR). The overarching theme of the ACIAR projects has been to improve the outcomes of smallholder and community forestry by addressing critical social, economic, biophysical and policy constraints, hence leading to improved livelihoods of the rural poor and positive environmental outcomes through the planting of trees. Accordingly, reliable data on trees grown by smallholders and communities have been (and continues to be) critical for a range of research activities.

Inventory data on woodlots have been collected for three separate but interrelated studies, concerning: (1) tree growth, performance and timber availability from private smallholder woodlots; (2) tree growth and performance of mixed-species plantings of native species; and (3) assessment of reforestation outcomes.

Financial returns from small-scale woodlots in the Philippines are low and many smallholders have become disillusioned with small-scale forestry. The aim of the ACIAR research program has been to improve the livelihoods of smallholder

farmers in Leyte Province through investigating ways of increasing financial returns from forestry, and promoting the adoption of these improved management methods. To support this, reliable inventory data relating to trees grown in smallholder woodlots was required for a number of purposes, including to:

- develop volume and yield tables for smallholder woodlots on Leyte Island (e.g. see Vanclay and Baynes 2005; Vanclay et al. 2008);
- determine the quality and quantity of timber that can be obtained from smallholder woodlots (e.g. Cedamon et al. 2011);
- develop growth and financial models for key tree species found in smallholder woodlots on Leyte Island; and
- investigate locational efficiency of on-farm versus centralised milling (Cedamon et al. in press).

There is much interest in the Philippines in domesticating indigenous tree species (Mangaoang and Pasa 2003; Gregorio et al. 2012), but almost no data on growth performance of these species are available. As part of ACIAR project ASEM/2003/052, data were collected from trials of the Rainforestation Farming System which were established on Leyte Island. Under this *rainforestation* system, 28 small-scale mixed-species plantations were established in local communities and on private properties in Leyte province (Milan 1997a, b; Milan et al. 2004). The main objectives of the rainforestation trials were to grow mixed-species plantations to meet social, economic and environmental needs (Schulte 1998, 2002). Approximately 100 endemic pioneer and Dipterocarp species, a limited number of exotic timber species and some fruit trees were used to create small plantations with the average area of about 1 ha (Margraf and Milan 1997). Fast-growing exotic species in rainforestation sites were first established to provide shade for the subsequent establishment of shade-tolerant species and to create an early income after 4–5 years from the harvest of timber and fruit (Göltenboth and Hutter 2004). Hence, the rainforestation sites offer a unique opportunity to investigate:

- growth characteristics of indigenous species when grown at higher densities and in species combinations that may otherwise not be experienced in natural forest (e.g. Ngyuen et al. 2012);
- factors affecting the success of indigenous species under varying environmental conditions, including microsite conditions;
- identification of complementary, facilitatory and competing species when grown within mixed plantations;
- how to best design highly diverse mixtures of indigenous species to provide production, support livelihoods and generate biodiversity benefits (see Gregorio et al. 2012 for how initial observations have been used to design further field trials);
- improved silvicultural techniques and management regimes for rainforestation sites to provide long-term benefits (Ngyuen et al. 2012); and
- the potential to use traits to create a predictive tool of how different species are likely to perform prior to plantation establishment.

Inventory data were also collected from 43 reforestation projects on Leyte Island (which included a number of rainforestation and tree farm sites) as part of a study to determine the success of reforestation projects in the Philippines. Little research has been conducted on performance of Philippine reforestation projects. Potential success drivers for reforestation have been identified by Le et al. (2012) and can be grouped into: technical/biophysical drivers; socio-economic drivers; and institutional, policy and management drivers. Inventory data were used to construct biophysical indicators of reforestation success, which along with social and economic data were used to identify the key drivers.

The Study Area

The study was conducted on Leyte Island (Fig. 1) which is located in the Eastern Visayas region (Region 8) of the Philippines archipelago, at about 9°55′N–11°48′N latitude and 124°17′–125°18′E longitude. Leyte is the eighth largest island in the Philippines, covering approximately 750,000 ha and consists of the provinces of Leyte and Southern Leyte.

The climate is tropical and characterized by relatively high temperatures, high humidity and abundant rainfall. Using the modified Coronas system of classifying climate (Coronas 1920), almost all of Leyte is 'Type IV', with rainfall relatively uniformly distributed throughout the year. Only the southeast corner is classified as 'Type II', with no dry season and with pronounced rainfall from November to January. Annual rainfall varies from approximately 1,700 mm in the southeast corner to approximately 2,300 mm over the rest of the island (Lantican et al. 2005). The island regularly experiences typhoons with winds often reaching more than 100 km/hr (Dargantes 1996). Most soils are relatively young and unweathered. However, steep slopes, high precipitation and frequent extremely heavy rainfall over short periods cause severe soil erosion (Pulhin et al. 2006).

Methods Used to Select Sites

The locations of smallholder woodlots, rainforestation sites and reforestation sites sampled as part of this study are indicated on Fig. 1. The following sections outline the methods and criteria used to select sites within each of these groupings.

Private Smallholder Woodlots

An initial reconnaissance on Leyte Island revealed a large number of scattered woodlots (Baynes 2005). A two-stage, probability proportional to size (PPS) sampling framework was used to select municipalities and then barangays from which woodlots were selected (as described in Herbohn et al. 2005). Spatial modelling with a Geographic Information System (GIS) was then used to calculate the area of land in each municipality suitable for forestry based on the criteria of suitable elevation and slope, proximity to local markets, and soil type. Land was

excluded if used for irrigated rice production, or classified either as a protected area (e.g. a national park) or for urban or industrial development. A detailed description of the method used to identify areas in Leyte suitable for smallholder forestry is provided in Baynes et al. (2007).

Seven municipalities were selected by PPS sampling, namely Anahawan and Libagon in Southern Leyte Province, and Bato, Hindang, Isabel, Leyte and Dulag in Leyte Province. A few woodlots identified as part of other project activities (see Baynes 2007) near the cities of Baybay, Albuera, Ormoc, Matalom, Mahaplag, Abuyog and Jaro in the province of Leyte and from Maasin and Macrohon in Southern Leyte Province—were also included in the tree measurement activities.

Rainforestation Sites (Mixed Species Plantings)

Twenty eight rainforestation sites were identified. Because of the relatively small number of sites, it was decided to undertake a census rather than sample woodlots. Ten of the 28 sites were rejected others: had been partially burnt or cleared for other agricultural

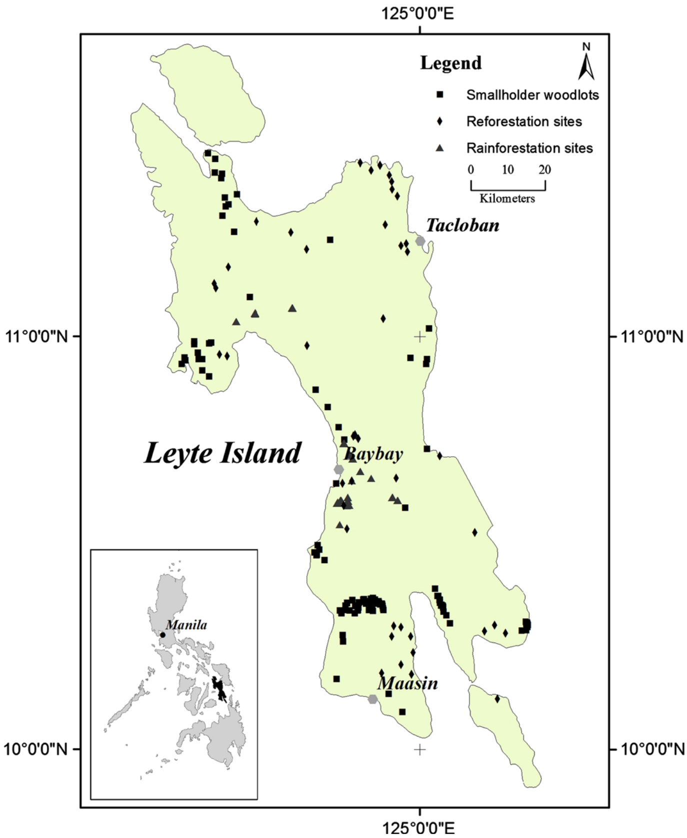

Fig. 1 Location of sites included in the inventory of smallholder woodlots, reforestation sites and rainforestation sites

Table 1 Site selection criteria

Selection criteria	Description
Location	Leyte Island (Leyte and Southern Leyte Provinces)
Key implementers	PO (People Organisation), DENR (Department of Environment and Natural Resources), NGO (Non-Governmental Organisation), Private.
Project type	CBFMA (Community-Based Forest Management Agreement), Rainforestation Farm Project, Reforestation (Refo) Contract, SIFMA (Socialised Industrial Forest Management Agreement), IFMA (Integrated Forest Management Agreement), Individual Private, Individual Company.
Funding source	Fund 101 (General fund), Fund 158 (Agrarian Reform Fund), Fund 102 (Foreign Assisted Fund).
Project size	$\geq$1 ha
Time since project commencement	At least 5 years
Revegetation style/ method	Monoculture Species (MONO), Mixed Introduced Species (MIS), Mixed Native Species (MNS)
Species	All tree species used for wood production except for mangrove species
Status	Plantations still existing at time of sampling
Project contact	A contact person must be identifiable and willing to be interviewed.

activities; were substantially affected by harvesting; did not have access approval from the land owners; or had few trees greater than 5 cm DBH (Ngyuen et al. 2012).

Reforestation Sites

When identifying reforestation sites, the following definition was adopted: "*Reforestation is the process by which trees are returned to areas from which they have been previously cleared. Reforestation can take many forms, ranging from establishing timber plantations of fast-growing exotic species through to attempting to recreate the original forest type and structure using native species*" (Le et al. 2012). A total of 62 reforestation projects were identified from Department of Environment and Natural Resources (DENR) records across Leyte and Southern Leyte. Subsequently, using stratified random sampling, 43 sites were selected according to the criteria in Table 1. The attributes of the selected reforestation projects are summarised in Table 2.

Gaining Access to Smallholders and Communities Woodlots

Smallholder Woodlots

Collecting inventory data would not have been possible without access to communities and smallholders. Limited information about smallholder woodlots and reforestation projects are held within DENR and local government offices, and accessing this information required the assistance of DENR and local government officials. The

Table 2 List of 43 surveyed reforestation projects and their attributes

Attributes	Number of projects	Relative proportion (%)
Province	43	
Leyte	31	72.1
Southern Leyte	12	27.9
Revegetation method	43	
MONO	17	39.5
MIS	19	44.2
MNS	7	16.3
Project type	43	
CBFMA	30	69.8
Non-CBFMA	13	30.2
Rainforestation farms	7	16.3
SIFMA	2	4.7
IFMA	1	2.3
Individual private	1	2.3
Other	2	4.7
Main funding sources	43	
Fund 101	24	55.8
Fund 158	3	7.0
Fund 102	12	27.9
Private individual or private company fund	4	9.3
Main implementers	43	
Peoples organisation	30	69.8
Individual/private	11	25.6
DENR	2	4.7

difficulties in accessing official data related to smallholder forestry in the Philippines have been discussed by Cedamon et al. (2011). As a cooperating partner in the research, the DENR Regional Executive Director had granted permission for research staff to access DENR records and registers relating to smallholder woodlots. Many of the records are maintained in local government offices, often by the Municipal Agricultural Officer (MAO) or the Municipal Environment and Natural Resources Officer (MENRO). The quality of record keeping varied considerably amongst agencies and between local offices, and in some cases, records were either not kept or were missing. Even after landowners who had established woodlots were identified from official records, a problem still remained about how to approach them. Philippine landowners are traditionally wary of government officials and other outsiders. In addition, local government is strong in the Philippines and the permission of municipal mayors is a prerequisite for entrance to communities. Hence, senior research staff made a direct approach to municipal mayors, and subsequently, to *barangay* officials.[1]

[1] A barangay is the smallest unit of local government in the Philippines and is approximately equivalent to a village.

In each municipality, with the permission of the mayor, research staff addressed a meeting of the local council to inform them of proposed research activities and to request permission to inventory their woodlots. This approach achieved three objectives. First, the aims and needs of the research were made public to a wide audience of local government officials and elected council members. Research staff were welcomed because they were seen as acting under the auspices of their elected officials, and security fears were allayed. Second, it was announced that there would be no payments made for access to woodlots because the stated aim of the research was to benefit the people of the Philippines and the project could not afford to pay for information. This created a sense of partnership between smallholders and project staff, and some site visits became almost quasi social visits. Third, the meetings provided the formal introductions necessary for other program activities, e.g. extension activities to assist smallholders to establish woodlots. Overall, the meetings and subsequent courtesy visits were highly time consuming, but without them, data collection could not have occurred. The method in which woodlots were selected and accessed varied according to woodlot type.

To help identify and subsequently gain access to smallholder woodlots in each municipality, it was first necessary to gain the support and permission of community and local government representatives and other gatekeepers. A courtesy visit was made to the municipal mayor and barangay captain, at which time a letter from the project leader was presented. Focus group discussions (FGDs) were then conducted in the seven sample municipalities, to which barangay captains or their representative, local government unit (LGU) officials and other stakeholders were invited. At these FGDs, lists of all smallholders with woodlots were compiled in consultation with barangay captains and municipal officials, particularly those from the Municipal Agricultural Office (MAO), along with representatives of the DENR. The woodlots identified through this process formed the tentative list of woodlots on which inventory plots were to be established. A criterion for selection was that woodlots had to be accessible, within one hour at normal walking pace.

Each smallholder was visited at their house and information about the purpose of the study was provided, including a letter from the Australian project leader. Verbal rather than written consent[2] to include their property in the study was then obtained. The boundary of the smallholding and each woodlot within it was recorded using a hand-held Garmin 76 GPS receiver. Blocks and plots were then delineated and tree measurements undertaken. Woodlots that had not been advised by barangay officials were sometimes identified during field visits. A woodlot qualified for inclusion in the sample if it contained at least one block of trees that had an area of 0.1 ha or greater and contained 100 or more trees.

[2] In a previous study, some community members misinterpreted written consent as being a means of signing them up for membership of an insurgency group, and were unhappy about providing written consent (Cedamon and Emtage 2005).

Rainforestation Woodlots

A list of rainforestation projects was obtained from the Institute of Tropical Ecology (ITE) at Visayas State University. After selecting the sites for the study, visits were made to the owners of the plantations to explain the research and to obtain consent to access sites and undertake research activities. Where sites were owned or controlled by a People's Organisation (PO), meetings were held with the PO officers. Meetings were also held with the relevant barangay officials before the field work commenced.

Woodlots at Reforestation Sites

A list of reforestation projects supported by the Department of Environment and Natural Resources (DENR) was obtained from the Forest Management Section (FMS) of the DENR 8 Regional Office in Tacloban. A meeting was held with the Regional Technical Director of the FMS to explain the purpose of the research, the activities to be undertaken and the type of data to be collected. Visits were made to Community Environment and Natural Resources Offices (CENROs) that have jurisdiction over the identified reforestation projects, to discuss the rationale of the research. These meetings provided crucial information for undertaking the research, including contact details for the People Organisations managing the reforestation projects, the PO officers and the key contact persons in communities where the projects were located. Before meeting the POs, visits were held with barangay captains (chairpersons) to gain clearance to enter the communities and for the safety of the team.

Data Collection Methods

Two fieldwork teams were established. One team (referred to as the survey team) comprised of two people (one with experience in survey methods and proficient in use of GPS and Mapsource), and was responsible for the survey of the perimeters of the smallholding and the selected woodlots within them. A second team (the tree measurement team), consisting of three enumerators, was responsible for establishing the plots and collecting site and tree data.

In most instances the survey team was accompanied by a guide (a tenant, owner or owner's relative) to help identify the boundaries of the farm and woodlots within the farm. A typical smallholding had a combination of various agricultural activities, including growing coconuts, small crops and rice, and often some timber trees, as woodlots or boundary plantings. A photo of the smallholding was taken featuring the farming activities and landscapes as a record of context within which the trees were being grown.

Data sheets were developed for recording information about the smallholding and associated woodlots. For the purposes of the inventory, woodlots were labelled 'blocks' and information was recorded about the block, plots within the woodlots, and trees within each plot. A sketch map was prepared for each smallholding,

recording locations of farming activities and outlining the features of the woodlots within the farm.[3] GPS coordinates were used to generate a boundary map of the farm and woodlots.

Within each smallholding, woodlots were identified as discrete groups of trees which were similar in species composition, age, size and form and occurred on similar topography, aspect, and slope and without any natural divide. Many smallholdings had several distinct woodlots or blocks, each of which were inventoried. Within each woodlot two circular plots were established. In order to assess edge effects, one plot was located in the block centroid and the other on the edge. Usually, a 5 m radius plot was established, but this was extended to 10 m where necessary to ensure at least seven trees per plot were included. To be included in the inventory, a woodlot had to be of sufficient size to accommodate two non-overlapping circular plots. Where the block was large and heterogeneous, up to four additional plots (but typically two) were established to gain greater representation of the block. These were located at the opposite side of the established edge plot, between the centroid and the boundaries.

The GPS waypoint of each plot was recorded and was marked with a ribbon tied to a tree at the plot centre for subsequent location by the tree measurement team. The plot centre was marked with a 12.5 mm diameter and 30 cm long PVC pipe driven in the soil leaving about 50–75 mm above ground. As a means of assisting in the subsequent interpretation and validation of data, each plot was photographed to document ground and canopy cover from two directions, due north and due south, with four photos being taken for each plot. These photos were taken as a means of visually checking anomalous results in subsequent analysis.

All trees within a plot with a DBH greater than 5 cm were allocated an identifying number, which was spray painted on the bole using red or orange paint. Numbering started at the tree closest to due north at the periphery and proceeded in a clockwise manner until the reference point was reached. Numbering was particularly useful for avoiding duplication of measurement of trees within the plot and facilitated rapid data collection. Aluminium tags coded with unique tree numbers were attached to the base of each measured tree using galvanised nails, with the tag always facing the centre of the plot.

The name and contact details of the smallholding owner, along with a unique farm code, were recorded on each farm data sheet. This code allowed easy identification of the municipality and barangay in which the smallholding was located. A sketch of the smallholding and the various blocks was also recorded on the 'farm' data recording sheet, along with the GPS waypoints for the smallholding boundaries. This labelling system allowed easy identification of where any tree was located and proved to be particularly useful in subsequent checking and analysis of data.

Separate data sheets were used to record information about each block, containing a sketch and including GPS waypoints, as well as information about biophysical properties and species. Plot sheets were used to record details about edaphic characteristics of plots, along with groundcover abundance, and stem tally

[3] Examples of recording sheets are provided in Supplementary Materials 1.

of trees, bamboo, palms and cycads with a DBH of not less than 2.5 cm. Along with DBH, distance and direction of each tree were recorded relative to plot centre points. Total height of every palm was recorded, but for trees, only the height of the tallest specimen was measured. Using a bark thickness gauge, the bark thickness was recorded at 10 cm below breast height at the two opposite sides aligned to the centre of the plot. Any bend or angle of lean of trees was noted on a recording sheet. The length of the trunk up to the first branch was measured, and crown depth and radii from four cardinal directions were recorded. The radii were the distance from the vertical projection of the crown edge at each cardinal direction to the base of the tree, with the horizontal distance being measured by a hypsometer. Locations of trees near the plot edge were recorded.

Each tree was assessed as to whether it contained commercial logs, with a minimum DBH of 10 cm set as a criterion for trees to be included. Trees for which log sections were estimated were sketched, taking note of their worst form, after viewing from every side. The stem was divided into sections based on its general form and straightness. In every section of the tree, large and small-end diameters (LED and SED) and length were recorded on the log data sheet. In most cases the SED of the lower section of the tree became the LED of the next upper section. A third diameter was recorded when forking was present. Sectioning took place up to the stem or any branch with LED of 10 cm. Four log grades were recorded: at least 70 % timber recovery of the log section total volume with minimum length of 1.2 m (A); at least 50 % timber recovery of the log section total volume, with minimum length of 1 m (B); at least 30 % timber recovery of the log section total volume, with 0.5 m minimum length (C); and at least 10 % timber recovery of the log section total volume, with no minimum length (D). A grade of D was automatically assigned for the forked sections of trees.

Data were encoded and entered into Microsoft Access. The original data sheets were photocopied in triplicate. The original forms are held in the ACIAR project office at VSU, with copies being held by designated members of the research team. The materials, equipment and instruments used in this study as well as a short description of their utility are reported in Table S1 in the supplementary materials.

Some Initial Results and Discussion

The inventory data provides important insights into the extent and nature of smallholder and community woodlots in the Philippines, and in this section we discuss some of the broad patterns which emerge from the data.

Inventory Findings for Smallholder Woodlots

Effectiveness of PPS Framework

Ninety-six smallholdings containing woodlots were identified in the seven sampled municipalities, and a further 10 smallholdings selected from outside of these municipalities. Round log volumes (total and merchantable) per sampling municipality are presented in

Table 3. The smallholdings that contained woodlots generally were small (less than 5 ha) and with irregular boundaries (i.e. high perimeter to area ratio) (Fig. 2). There was high variation in the number of woodlots between municipalities.

There was no significant relationship ($P > 0.05$) between the total suitable area for woodlots (the basis for PPS sampling) in each the seven municipalities selected and the number of woodlots per municipality, or the estimated volume of timber or area of woodlots in each municipality. While a lack of a relationship is disappointing, it is possible that a larger sample size may have revealed a significant relationship. In addition, it is possible that the suitability measures used to determine available area for woodlots were poorly specified, or did not reflect other important factors that influenced the establishment of woodlots.

Size and Shape of Smallholder Woodlots

Most smallholder woodlots were found to be small, with more than half being 1 ha or less (Fig. 3). There is a weak but statistically significant relationship ($r^2 = 0.146$, $P < 0.05$) between smallholding size and area of the smallholding planted to woodlots (Fig. 4). There is, however, a clear bimodal distribution of proportion that the woodlots comprise of the total smallholding area (Fig. 5). This bimodal distribution suggests that there are probably two major motivations for smallholders to establish woodlots. When the smallholding is used mainly for agricultural production, smallholders tend to establish small woodlots on unproductive land.

Table 3 Round log volumes (total and merchantable) per sampling municipality. Estimates based on centre plot data only

Municipality	PPS municipality	Woodlots	Total volume (m^3)	Merch. vol. (m^3)	Merch. vol. (as % of tot. vol.)
Anahawan	Yes	11	883.3	450.2	51.0
Bato	Yes	71	4,362.4	1,664.8	38.2
Dulag	Yes	3	173.3	94.6	54.6
Hindang	Yes	5	308.3	169.0	54.8
Isabel	Yes	25	3,308.1	1,527.2	46.2
Leyte	Yes	25	1,723.6	752.3	43.6
Libagon	Yes	23	1,787.7	852.9	47.7
Abuyog	No	3	108.0	45.4	42.0
Albuera	No	1	17.0	7.3	42.9
Baybay	No	4	262.1	105.2	40.1
Jaro	No	1	12.5	7.9	62.6
Maasin City	No	3	168.8	56.8	33.7
Macrohon	No	2	77.7	40.8	52.5
Mahaplag	No	3	509.1	243.2	47.8
Matalom	No	5	155.6	61.2	39.3
Total		185	13,857.6	6,078.7	43.9

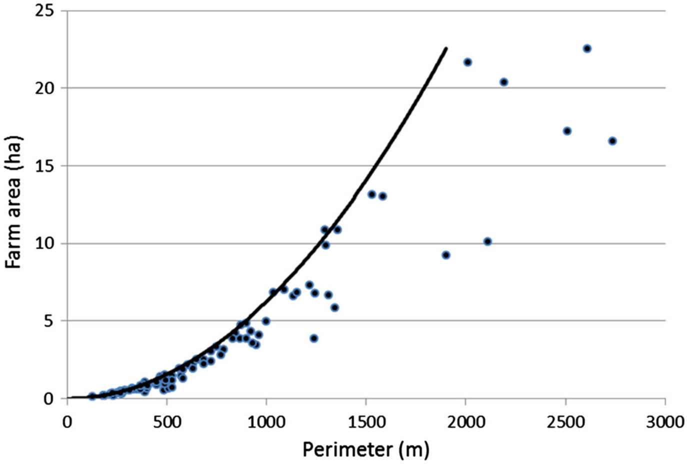

Fig. 2 Relationship between perimeter of the smallholding (farm) and smallholding area. The *solid black line* represents the efficient frontier for the minimum perimeter to farm area assuming linear farm boundaries

Fig. 3 Size distribution of smallholder woodlot plantings

In cases where woodlots occupy more than 90 % of the smallholding, it is possible that the owners are using trees as a means of maintaining tenure over the land and preventing squatters from using the land in their absence.

Species and Planting Configurations

Gmelina arborea and *Swietenia macrophylla* were by far the most common species found in smallholder woodlots, being recorded in 72 and 44 of the 106 smallholdings

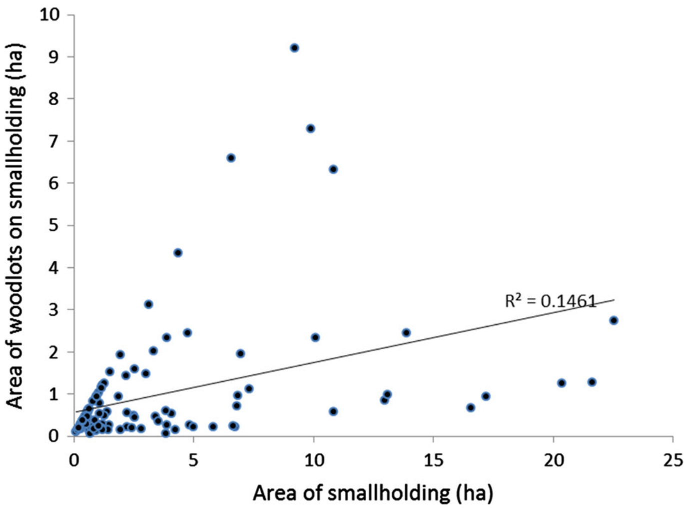

Fig. 4 Relationship between smallholding size and aggregate woodlot size on smallholding. Multiple woodlots on a single smallholding are aggregated

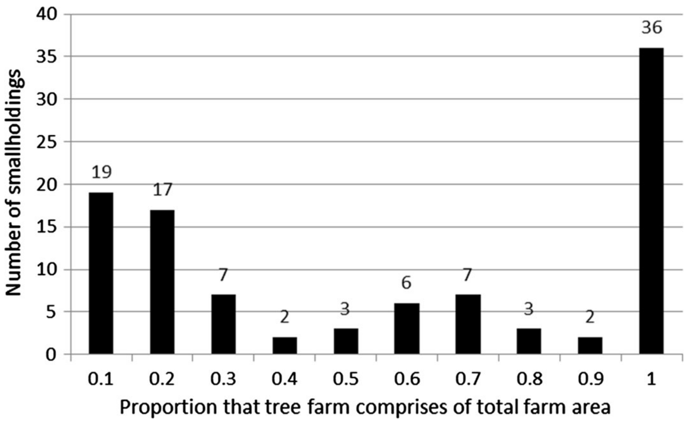

Fig. 5 The proportion that woodlots comprise of total smallholding area

inventoried (Table 4). The next most common species in terms of number of individuals recorded was *Acacia mangium* (found on only six smallholdings). Of the 36 species recorded in woodlots, half were recorded at three or fewer sites. Most of these are indigenous species and it is likely that most were recruited to the woodlots through natural distribution processes rather than being deliberately planted, with the three likely exceptions being mango, coffee and cacao. This suggests that smallholder woodlots have the potential to improve tree biodiversity at a landscape scale, even if they are established as monocultures and not actively managed for biodiversity purposes.

Table 4 Most common species recorded in plots established in smallholder woodlots in Leyte[a]

Species name	Common name	No. of trees	No. of small-holdings	Mean DBH (m)	Mean height (m)	Mean age (y)	Indigen-ous
Gmelina arborea	Yemane	2,760	72	15.5 (5–65.8)	14.2 (1.1–27.3)	12 (3.8–20)	N
Swietenia macrophylla	Mahogany	1,153	44	13.3 (5–68)	12.8 (4.3–24.6)	10.1 (3.8–27.3)	N
Cocos nucifera	Coconut	184	58	29.4 (13.2–48.3)		11.2 (5.3–27.3)	N
Acacia mangium	Mangium	118	6	15.2 (5.5–37.2)	14.9 (7.7–22.3)	7 (4.8–19.9)	N
Eucalyptus deglupta	Bagras	56	1	17.1 (6.5–34.4)	16.8 (9.2–26.8)	14.8 (13.7–16.7)	Y
Acacia auriculiformis	Auri	39	6	13 (5.1–33.9)	14.3 (8.8–22.9)	8.4 (4.8–17.6)	N
Nauclea orientalis	Bangkal	32	3	15.8 (7.8–28.3)	14.9 (3.4–24.9)	14.9 (13.7–19.9)	Y
Leucaena leucocephala	Ipil-ipil	30	15	15.7 (5.5–32)	12.5 (6.7–17.4)	11.2 (3.8–27.3)	N
Artocarpus blancoi	Antipolo	28	16	12.5 (5.5–40.5)	11.9 (6.8–18.8)	15 (6.8–27.3)	Y
Artocarpus heterophyllus	Nangka	20	9	12.8 (6.1–33.3)	9 (6.1–16.4)	12.9 (5.7–27.3)	Y
Samanea saman	Raintree	18	2	41.4 (22.5–58.8)	18.9 (11.4–22.7)	15.2 (13.7–15.5)	N

[a] Figures in parentheses are ranges

Coconuts were recorded in plots established in woodlots in 58 smallholdings. This reflects the common practice of smallholders establishing woodlots in coconut plantations by underplanting with timber species. Typically underplanting occurs in coconut plantations that are reaching the end of their productive life. While there is a market for *cocolumber*, Philippine Coconut Authority regulations require replanting of an equivalent number of coconut palms to that removed, which acts a disincentive for smallholders to remove coconut palms prior to planting of timber trees.

Most woodlots were found to be 4–16 years old (Fig. 6), with few blocks older than 20 years. The small number of younger blocks is in part due to young blocks (<3 years old) being excluded from the sample. In addition, it appears that few new woodlots were being established because of past unfavourable forestry experiences of smallholders in terms of both tree growth and market access (particularly in the case of gmelina). From Fig. 6 a marked shift from gmelina to mahogany is apparent, with mahogany dominating the 4–8 year age class, and gmelina dominating the 12–16 year age class. The transition to mahogany started from 1994 to 1998 (8–12 years before the woodlot inventory was undertaken in 2006), and has escalated to the extent that now little gmelina is being planted by Leyte smallholders. The large proportion of gmelina planted 12–16 years ago was associated with the promotion of this species by various government agencies and NGOs. However, poor silviculture and site selection, combined with a lack of access to markets, have led to many smallholders having highly negative perceptions about this species.

Estimated Total and Merchantable Log Volumes

Table 4 provides estimates of the gross and merchantable volumes of timber from woodlots from the sampled municipalities in Leyte. Notably, volumes of timber per smallholder woodlot vary widely between municipalities. On average, the estimated merchantable volume is only 44 % of the gross volume (Table 3), confirming that poor silviculture by smallholders has failed to capture anywhere near the full potential of their sites. Hence improved silviculture could considerably improve the

Fig. 6 Age distribution of woodlots by dominant species

Table 5 Most common species recorded in 2006 in plots established in Rainforestation Farming System sites in Leyte. Ranges are given in parentheses[a]

Scientific name	Common name	No. of trees	Mean DBH (cm)	Mean height (m)	Mean age (years)	Native or exotic	Fruit tree	Diptero-carp
Swietenia macrophylla	Mahogany	158	11.8 (5.0–40.0)	9.1 (3.5–17.6)	9.3 (4–11)	E	N	N
Terminalia microcarpa	Kalumpit	90	13.3 (4.9–31.5)	9.6 (3.0–18.8)	8.4 (6–10)	N	N	N
Vitex parviflora	Molave	86	11.3 (5.2–26.5)	7.5 (0.0–12.7)	9.2 (7–11)	N	N	N
Casuarina rumphiana	Mt agoho	70	14.9 (6.7–29.5)	9.9 (4.6–15.2)	10.0 (6–11)	N	N	N
Parashorea malaanonan	Bagtikan	67	10.1 (4.6–18.9)	7.9 (3.0–11.9)	7.6 (7–9)	N	N	Y
Gmelina arborea	Gmelina	59	21.9 (6.1–49.3)	14.6 (4.9–25.5)	9.9 (8–10)	E	N	N
Shorea contorta	White lauan	51	10.6 (5.1–23.8)	8.5 (0.0–14.7)	8.0 (5–10)	N	N	Y
Dracontamelon dao	Dao	44	12.2 (5.5–27.8)	9.2 (0.0–17.0)	9.5 (6–11)	N	N	N
Shorea polysperma	Tangile	41	12.4 (5.0–24.3)	9.5 (4.5–12.6)	7.0 (7–7)	N	N	Y
Pterocarpus indicus	Narra	36	10.1 (5.0–24.5)	8.2 (3.9–16)	9.3 (8–11)	N	N	N
Hopea plagata	Yakal-saplungan	35	8.0 (5.1–13.0)	7.6 (4.4–11.0)	7.9 (5–10)	N	N	Y
Cassia siamea	Thailand acacia	29	10.3 (5.2–14.7)	8.4 (4.2–13.2)	10.0 (10–11)	E	N	N
Tectona grandis	Teak	26	15.4 (5.5–24.7)	11.3 (4.0–14.0)	10.0 (10–10)	E	N	N
Agathis philippinensis	Almaciga	24	10.5 (5.6–19.7)	6.2 (3.6–11.9)	9.4 (9–10)	N	N	N
Melia dubia	Bagalunga	24	22.1 (8.0–49.3)	13.4 (0.0–21.6)	9.4 (6–11)	N	N	N
Calophyllum lancifolium	Bitanghol sibat	22	8.2 (5.4–12.1)	6.3 (3.4–9.2)	8.8 (6–10)	N	N	N
Shorea palosapis	Mayapis	22	14.3 (7.5–23.6)	10.0 (7.5–12.0)	7.0 (7–7)	N	N	Y

[a] Figures in parentheses are ranges

yield of merchantable timber and the financial returns to smallholders. This suggests that training programs and extension materials directed at improving silviculture have the potential to substantially improve the productivity of smallholder woodlots.

Inventory Findings for Rainforestation Sites

A total of 1,097 trees of 74 species were recorded in 87 plots located across 18 rainforestation sites (Table 5, see Table S1 in Supplementary Materials for full list of species recorded). Of the 74 species, 56 were endemic to the Philippines and 18 were exotic. The most commonly planted endemic species were *Terminalia microcarpa, Vitex parviflora, Casuarina rumphiana and Parashorea malaanonan.*

Swietenia macrophylla, a species exotic to the Philippines, was the most commonly recorded species in the rainforestation plots, with gmelina (also an exotic) also being commonly found. Overall, exotic species comprised over 30 % of the trees recorded. This high proportion is a surprising result, given that the rainforestation program strongly promoted growing native species. Discussions with smallholders at the time of measurement suggest that many favoured exotic species including mahogany and, to a lesser extent, gmelina. In some cases exotic species appear to have been planted as part of the rainforestation program at the smallholder's request, and it appears that smallholders commonly made subsequent plantings of exotic species. The primary motivation for smallholders planting exotics appears to be that they believed these species have more rapid growth. Related to this, farmers were familiar with exotic trees—particularly gmelina, mahogany and *A. mangium*—because these were widely planted during the National Forestation Program of DENR in the 1980s and 1990s.

There were 14 fruit tree species in a total of 77 species found at rainforestation sites, accounting for 6.5 % of total trees measured. While the precise proportion of fruit trees originally planted is unknown, it likely that the current low proportion recorded is in part due to high mortality of the trees originally planted due to competition from the forest trees. The average height of fruit trees was about 3.5 m less than that of non-fruit species, suggesting that the fruit trees were overtopped and many were likely outcompeted by faster growing species. It was noted by smallholders that most of the fruit trees never bore fruit due to shading.

Lessons and Insights

Few of the woodlots appeared to have been thinned, which has resulted in overstocked woodlots with many small diameter stems. For gmelina in particular, many of the stems also had poor form. In the case of the rainforestation woodlots, overstocking and a subsequent failure to thin resulted also in the failure of fruit trees to bear fruit and probably also in high fruit tree mortality. It is clear that an extension program is needed to improve the silviculture of woodlots, for both the production of timber and management for non-timber products (e.g. fruit production in the case of rainforestation plantings). Smallholders appear to be receptive to

extension advice (Baynes et al. 2009, 2011a), but training and extension materials will only be useful if they are tailored to information needs and skills requirements of smallholders (Baynes et al. 2011b). Technical advice is useful for smallholders to adopt successfully the introduced technologies (Baynes et al. 2007). In particular 'hands-on' training is effective, but this should not be delivered as a one-off event, but rather as a process involving regular follow-up and presence of extension workers, especially during the early stage of technology adoption (Baynes et al. 2011b).

One of the lessons to come from the current inventory study is that the small additional time and expense taken to make the plots easy to locate again at a later date (e.g. mapping the location of plots, marking the centre of each plot with plastic piping, labelling each tree with aluminium tags and mapping the location of each tree within the plot) can greatly increase the utility of the plots over traditional temporary plots. In some cases, we returned to the plots to check anomalous data. In the case of the plots established in the rainforestation sites, careful recording of plots we have been able to make an additional two series of growth measurements over a period of 6 years, something that was not envisaged at the time of the initial sampling. We have also been able to use these plots as the basis of other studies (e.g. seedling recruitment, functional traits), and have been able to use previously collected data to help explain results in these other studies.

Collection of information from smallholders and community members through interviews conducted in conjunction with both the smallholder woodlot and reforestation inventories has proved valuable for a variety of purposes. Socio-economic data have initially allowed identification of such basic information as plantation age and management practices (e.g. Cedamon 2012). In subsequent data analysis it has been invaluable in interpreting and explaining patterns in the inventory data.

Undertaking the inventory of smallholder and community woodlots has proved much more complex than an inventory of industrial-scale plantations. Engaging and consulting with local communities and smallholders prior to fieldwork is essential to gain access to the woodlots. In many cases engagement with the community is also necessary to identify where the woodlots are located, and to collect basic information including plantation age and initial establishment practices. For industrial forestry estates, this information would have been systematically recorded and be readily available, and there would usually be no issues with gaining site access. In contrast, we found difficulty in both identifying and gaining access to smallholder and community woodlots. The access procedures described in this paper are appropriate to the Philippines; in other developing tropical countries, similar procedures are likely to be required, albeit modified to suit local customs and norms.

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